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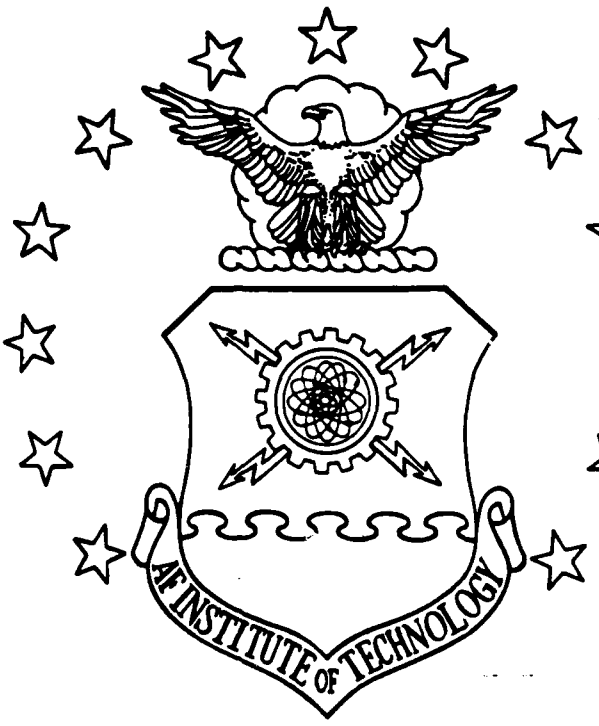

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Wright-Patterson Air Force Base, Ohio

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AFIT/GCM/LSQ/88S-9

A STUDY OF THE EFFECT OF DUAL SOURCING ON OPERATION AND SUPPORT

THESIS

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AFIT/GCM/LSQ/88S-9

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A STUDY OF THE EFFECT OF DUAL SOURCING ON OPERATION AND SUPPORT

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Contracting Management

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September 1988

Preface

The purpose of this research was to examine the impact of dual sourcing on operation and support. Although a lot of research is now being published which examines the effect of dual sourcing on acquisition, this appears to be the first published attempt at examining dual sourcing and operation and support. As a first attempt, it serves an exploratory purpose: defining the boundaries of the problem and areas for future concentration.

I used every method available to accomplish this purpose: life-cycle cost study, interviewing experts, and a manual search for case studies. The life-cycle cost study yielded a model and some items to study, but the Air Force currently does not have the cost data for the items. In other words, it was impossible to validate the model at this time. However, some insights were gained which I believe will help future researchers as more data and experience become available. Remember, dual sourcing is a fairly recent phenomenom; not a lot of experience is available--especially in operation and suppport.

I was amazed at how helpful everyone was. The Air Force employs some wonderful people. A special thanks is in order for Tom Frantz and the rest of his crew at HQ-AFLC. Larry Milligan and Bob Tonar of the Defense Electronics Supply Center were major contributors to the success of this thesis. Ernest Curry and his friends at the Air Force standardization office did their utmost for me on the basis of a phone call. Major Hicks took time out of very busy schedule to explain the F-16 program to me and some of the dual sourcing impacts. The AFIT library people cut many hours off of the research by going out of their

way to be of help. I've never seen anything like it in Government or private service--except perhaps in insurance salesmen. They all are wonderful.

A special thanks is in order for my thesis advisor. An exploratory study is a difficult assignment. Also, AFIT does not train its students in how to do an exploratory thesis. An unusually heavy burden was placed on Dr. Roland Kankey as he guided and encouraged me through this research. I deeply appreciate his help. It may sound trite, but without his help this thesis would have never even been attempted--much less brought to completion.

The greatest burden of a thesis probably falls on the family. I know they will appreciate having me really 'home', again.

Stephen C. Miller

Table of Contents

List of Tables

Abstract

Past research on dual sourcing dealt with acquisition. Since typically the majority of a major system's cost occurs during operation and support, this has left a large gap in the literature. Also, the impact of dual sourcing on supportability and readiness has not been examined. This thesis is a first attempt to plug that gap.

The thesis attempted to answer three questions:

1. What operation and support elements are affected by dual sourcing?

2. Of the elements affected, which are significant, and do they become more--or less--expensive?

3. What does recent experience with O & S effects of dual sourcing tell the DOD manager?

This was attempted using a life-cycle cost model, through case studies, and expert opinion. Although an appropriate cost model was developed, cost data was not available to exercise it. Current databases have not been in place long enough to provide the necessary data. Also, many of the cost elements of interest are not collected.

The literature, case studies, and experts, revealed that the primary determinant of the impact of dual sourcing on operation and support comes from the degree of configuration standardization imposed by the method used to create or maintain additional sources. For this reason, experts in standardization provided a wealth of detail useful to this study.

Four of the methods used to create additional sources put identical items in inventory. Form, fit, and function dual sourcing does not. If identical items are produced, there may be configuration control problems among manufacturers, but competition in spare parts and maintenance can be a real benefit.

The literature predicted that form, fit, and function dual sourcing would produce additional costs and inconveniences during operation and support. This is the result of maintaining multiple configurations of an item in inventory. The case studies and experts suggest that this can indeed be the case, but that adequate planning can reduce negative impacts significantly.

A STUDY OF THE EFFECT OF DUAL SOURCING ON OPERATION AND SUPPORT

I. Introduction

Chapter Overview

The Department of Defense has turned to dual sourcing in order to increase opportunities for competition. The Government believes competition can hold down cost, while not sacrificing quality and other benefits. Dual sourcing extends competition into production, traditionally a sole-source environment

Researchers have only studied the impact of dual sourcing during development and production. This leaves a significant gap. The operation and support phase of a major system's life is typically the most expensive. Also, this concentration on acquisition neglects the impact of dual sourcing on readiness and support. This thesis attempts to plug that gap. It is a first look at the rest of the story: the effect of dual sourcing on operation and support.

Background

The Acquisition Goal. The Department of Defense recognizes that price is not the only factor to consider when purchasing weapons and supplies. Kernan and Mencker cite the mandate in the Armed Services Procurement Act of 1947 that:

> Award shall be made...to the responsible bidder whose bid...will be most advantageous to the United States, price and other factors considered (Kernan and Menker, 1976:1-1).

Balancing 'price and other factors' is a goal in both Government and commercial markets. During a seminar, William J. Devaney, President and General Manager of Stanley Vidmeir, Inc., said

> I heard the word price quite a bit this morning. I cringe when I hear that. The name of the game is value (Purchasing World, 1984:56).

This balancing of price and other factors to obtain the most advantage, or value, is difficult. Difficult choices must be made. Dr. James P. Wade, Jr., an Assistant Secretary of Defense for Acquisition and Logistics, had this to say:

> Our acquisition strategies might be good, they might be fast, and they might be cheap, but I think we can say that they can't be all three at the same time...(Correll, 1986:54).

From time to time, the choice of emphasized factors changes. Powers and Recktenwalt believe that the launching, in 1957, of SPUTNICK, the first successful orbiting satellite, was such a time. Time and technology--more than price--became the driving factors (Powers, 1978:12-13).

The Problem: increasing cost. Somewhat later alarm began to rise when it was realized that weapon costs were getting out of hand. The Department of Defense realized that to continue to acquire weapons without a greater emphasis on cost would result in a force effectively impossible to both buy and use.

Increase in unit purchase price. The purchase price of aircraft, for example, was--and is--rising exponentially (Green, 1984:36). Norman R. Augustine, former Assistant Secretary of the Army, pointed out--somewhat facetiously--that extrapolating present trends into the next century leads to an alarming conclusion: the cost of

aircraft will continue rise to the point that this country will be able to afford only one.

> The unit cost of major items of military hardware has been increasing at a significantly faster pace than the DOD budget itself, or for that matter, the Gross National Product. It is a relatively straight forward calculation to show that if the trends which have prevailed so consistently over the last half-century were to continue for a few more decades, we will reach a point in the year 2036 where the Defense Department will literally be able to afford only one aircraft (Augustine, 1975:34).

He gave similar projections for tanks and ships. Of course, he states that somewhere a correction would eventually be made. To allow such a trend to continue would be idiotic.

Increase in operation and support costs. At the same time that purchase price was increasing, analysts noticed that the cost to use and maintain weapons was also becoming unacceptable. Botkin (1986:4) reports that in 1968 operation and support costs exceeded 50% of the cost of weapons systems. In 1974, Department of Defense operation and support costs rose to 70% of the budget (Botkin, 1986:5).

With these numbers in mind, Boileau, in his article 'I dreamed We Went Nowhere in our Solid Gold Airplane,' (1976: 6-7) maintained that:

> You don't have to be an economics expert to conclude...that DOD manpower and operations costs are chewing up the budget, such that in time there won't be money left for procurement.

Of course, his extrapolation has not come to pass. Still, operation and support costs accounted for a majority of DOD expenses between 1980 and 1985. Actual figures were 56.9, 56.6, 55.8, 53.9, 52.1, and 57.1 percent of the DOD budget during the years 1980 to 1985, respectively (Botkin, 1986:5).

Although the money left over for procurement has not dropped to zero, as predicted in 1976, the problems caused by high operation and

support costs still plague the Department of Defense. In 1986, Dr. James Wade felt it was important to point out that operations and support costs lock funds into maintenance and support of existing systems. As a result, there are fewer discretionary funds for new weapons. Since new weapons cannot be bought, old weapons must be kept in service longer (Wade, 1986:27-29).

The solution. Two of the methods that the Department of Defense adopted to attack these increasing costs were--and are-- 1) an emphasis on life-cycle costing, and 2) increased use of competition during acquisition.

Life-cycle costing. To attack the increase in operation and support costs, the Department of Defense started to evolve the life-cycle cost (LCC) concept in the early 1960s.

> The objective of life cycle costing is to lower a system's life cycle cost by striking a balance between acquisition and O & S costs (Sims, 1978:12).

The Department of Defense felt that too much emphasis was being placed on acquisition cost--and not enough on costs incurred during the rest of the system life-cycle (Kernan and Menker, 1976:1-1).

Of course, the result of this emphasis was a host of regulations requiring the Department of Defense to carefully consider life-cycle cost before awarding anything other than a small contract. For example, the Federal Acquisition Regulation (FAR) requires an acquisition plan that asks for a discussion of 'how life-cycle cost will be considered'. 'If not used,' the decision maker must 'explain why' (Department of Defense, General Services Administration, and National Aeronautical and Space Administration, 1984:7-105). AFR 800-8 requires that 'plans [be]

established which ensure application of LCC disciplines throughout the acquisition process' (Department of the Air Force, 1986:15). DOD 5000.1, Major System Acquisitions, mandates that: 'A cost effective balance must be achieved among research, development, production, and ownership costs of major systems...' (Department of Defense, 1986b;2).

Some other major regulations requiring life-cycle cost analysis are:

DODI 5000.2 - Major System Acquisition Procedures (Department of Defense, 1986c),

DODD 5000.4 - Office of the Secretary of Defense, Cost Analysis Improvement Group (Department of Defense, 1980), and

DODD 5000.39 - Acquisition and Management of Integrated Logistics Support for Systems and Equipment (Department of Defense, 1983).

Increased use of competition. To combat the burdensome rise in purchase price without sacrificing other goals, the Government has turned to increased use of competition. Former Secretary of Defense Weinberger held the widely-shared view that:

> [We] must give greater attention to obtaining competition in the placement of contracts by all DOD components. The benefits of competition are well known. Competition serves to reduce costs, improve quality, and enhance the industrial base (Weinberger, 1982:1).

The legislative branch also shares this opinion. Representative Jim Courter (R-N.J.) said:

> We recognize that competition doesn't solve all problems, but generally we believe that there has been too little of it, and we want more of it (Correll, 1986:55).

In 1984, Congress passed the Competition in Contracting Act (CICA). CICA further emphasized competition (Little, 1986:39-40). Also, for the first time dual sourcing was specifically permitted as a means of

reducing cost (Little, 1986:40; General Accounting Office, 1984:10). Before then it was only expressly authorized in order to promote national defense and aid industrial mobilization (General Accounting Office, 1984:10).

Dual sourcing allows the Government to have competition during production. Traditionally, the Department of Defense has had competition during concept development and prototyping, but has awarded a single contract for production to the winner of the prototyping competition. From then on, during production, the military had only one source. Dual sourcing allows competition to be continued (Sellers, 1983:10).

Since CICA the Department of Defense has attempted to apply dual sourcing whenever it seemed to hold the promise of price reduction. Little (1986:11) mentions plans to dual source several major programs: the MX missile, the cruise missile, AMRAAM, and the engines of the F-16. One enthusiastic supporter is General Eaglet, formerly Air Force Armament Division Deputy Commander for Research, Development, and Acquisition. Dornheim, in his article "Use of Dual Sourcing Increases in Weapons Systems Production," quotes him as saying:

> We're trying to get multiple sources for everything that we have coming down the pike, even at the expense of considerable turbulence from time to time, or possible delay in the program (Dornheim, 1986:48).

Specific Problem

Logically, with O & S costs running at around 50% of the DOD budget, policy makers would want to carefully examine the affect of every acquisition policy on O & S costs. But a literature review

reveals no instance where researchers analyzed the impact of dual sourcing on operation and support. Only acquisition has been studied. Without this knowledge, the Department of Defense cannot, for example, effectively 'lower a systems life-cycle cost by striking a balance between acquisition and O & S costs' (Sims, 1978:12)--the objective of life-cycle cost analysis--when dual sourcing is involved. Ernest Curry, life cycle cost analyst, confirms this.

> The total impact of competition cannot be determined solely from acquisition costs. Consideration must be given to the maintenance concepts to determine whether the acquisition cost savings are eroded by the addition logistics support required ...
>
> The potential acquisition savings from competition could be significant. However, the total LCC impact will require an in-depth analysis including various maintenance concepts (Curry, undated:2).

Importance of the Research

Total life-cycle cost--not just acquisition cost--should be examined when studying dual sourcing. Operation and support costs can form most of a system's life cycle cost. A former Deputy Assistant Secretary of Defense for Logistics and Material Management said that:

> The cumulative operations and support cost over the life of major weapon systems invariably exceeds total development and production costs (Webster, 1982:5-6).

Why, then, have just development and production, or acquisition, been examined when dual sourcing has been studied? Perhaps Robinson and Sullivan found the reason during their study of dual-sourced ship building. They believe that the program managers just do not know how:

> Long-term costs versus instant savings have not been examined in depth. This is more due to a lack of methodology than a lack of interest or desire on the part of program officers (Robinson and Sullivan, 1986:62).

Implied in their conclusion is an unfulfilled need for information on the impact of dual sourcing on the rest of the life cycle costs, namely, operation & support and disposal costs.

Thus, studies and decisions examining the affects of dual sourcing which neglect life-cycle cost are not just ignoring the regulations cited earlier; they are also ignoring the largest proportion of life-cycle costs for major systems.

Objectives of the Study

The objectives of this study are to address this important issue, to plug the significant gap left by researchers, and to supply information to aid decision makers in determining the impacts of dual sourcing options on operation and support.

Investigative Questions

The answers to the following questions should provide information necessary to help make better decisions on the effect of dual sourcing on the operation and support phase of the life cycle.

1. What operation and support elements are affected by dual sourcing?
2. Of the elements affected, which are significant, and do they become more--or less--expensive?
3. What does recent experience with O&S effects of dual sourcing tell the DOD manager?

Limitations of the Study.

Operation and support cost emphasis. Since many studies have already examined the impact of dual sourcing on acquisition, this study only deals with operation and support (Air Force Business Research Management Center, 1987; Beltramo, 1986; Grosson and Augusta, 1986).

The effect of dual sourcing on the last phase of life-cycle costs, disposal, will not be studied. According to the Directorate of Cost Analysis, Comptroller, Aeronautical Systems Division at Wright-Patterson AFB, disposal costs 'are often very small in comparison to the other categories' and are, therefore, 'seldom estimated in most analyses' (May, 1982:2-2). They can become significant if toxic materials, for example, are involved (May, 1982:2-2).

Cost Emphasis. Cost reduction is the most often mentioned reason for dual sourcing (General Accounting Office, 1984:10). For this reason, this study focuses heavily on the economic effect of dual sourcing on operation and support.

Other goals or impacts not mentioned include those which are programmatic (schedule, quality, etc.), strategic (surge capacity, industrial base), and socio-economic (small and minority business goals, etc.) (General Accounting Office, 1984:16-19).

Avionics Emphasis. Most of the information used comes from the area of avionics. However, the information presented here should be useful to managers of other types of equipment as well.

II. Literature Review

Chapter Overview

Although little, if any, empirical research has been done on the impact of dual sourcing on operation and support, experts have expressed their opinions in their studies of acquisition costs. They believe that two dual sourcing options may influence operation and support costs: 1) the method chosen to create the second source, and 2) the method chosen to divide the award among the manufacturers.

Creating the second source

Four of the five methods used to create additional sources require all sources to produce the same standard configuration, while one does not. This effectively divides dual-sourced items into two categories. These terms, among others, are defined in Appendix A. These categories impact operation and support differently.

Identical configurations. Four of the methods used to create a second source require contractors to produce identical configurations: technical data package, directed licensing, leader-follower, and contractor teaming. This has both its costs and benefits.

Configuration Control. In order to keep items from each manufacturer identical, extra effort must be made in configuration control.

> Maintenance of the data package and coordination of engineering changes are more complicated when more than one contractor is involved in production of the system (Sellers, 1983:13).

Grosson and Augusta believe that this problem can extend into the operational life of the item or system. Configuration control must

continue to be maintained as the item or system evolves with use (Grosson and Augusta, 1986:35). Some doubt that identical configurations can ever be achieved. After studying dual-sourced ship acquisitions, Robinson and Sullivan (1986:30-31) concluded that it is impossible to get completely identical configurations.

> Even if all systems and subsystems were identical in the two ships, methods of fabrication at the two shipyards would generate differences in the final product (Robinson and Sullivan, 1986:30).

They feel the affects of dual sourcing will linger because of these configuration problems.

> The long-term effect of having two classes of ships in every program that is dual sourced will not be felt until years after they are in the fleet being supplied and maintained to different configurations (Robinson and Sullivan, 1986:63).

Non-Identical Configurations. One method of creating or maintaining additional sources does not require identical items: form, fit, and function (F3). An F3 configuration requirement makes the internal configuration the responsibility of each manufacturer. Thus, many of the configuration control problems are by-passed. But form, fit, and function has its own problems.

For example, if the Government wants to be able to repair the item itself, multiple configurations require multiple sets of technical orders--one for each configuration (Robinson and Sullivan, 1986:17. The Government must budget for training time and material for each configuration (Grosson and Augusta, 1986:35; Sellers, 1983:13), and perhaps additional test equipment (Robinson and Sullivan, 1986:17; Sellers, 1979:55). Also, since the internal configurations are different, repair requires stocking of the internal parts from each manufacturer.

This runs counter to the Air Force standardization effort. Standardization reduces the number of items in inventory performing the same function. Starting with several unique systems, subsystems, modules, or piece parts; standardization replaces the functional equivalents with either F3 or identical items. Dual sourcing's starting point for evaluation, on the other hand, is a unique item. If F3 dual sourcing is used, the result is two or more items performing the same function. Standardization moves toward simularity of items; F3 dual sourcing moves away from simularity items. In other words, F3 dual sourcing destandardizes.

Rosensteel mentions some operation and support cost elements impacted by standardization. These are listed in Table I. Notice the simularity between the cost elements listed in Table I and those mentioned earlier that are impacted by dual sourcing during operation and support. Also, notice that the impact of standardization is, in many cases, the opposite of dual sourcing. In other words, standardization impacts many of the same elements that dual sourcing does, but in the opposite way. Both techniques can result in form, fit, and function items. This also causes some simularity in the end result of both techniques.

TABLE I

List of O & S Cost Elements Relevant to Standardization

Spares. Common systems require fewer spares than when different aircraft have unique subsystems.

Support Equipment. Quantity reduced because one common system is likely to require less equipment than several systems performing the same function.

Maintenance Training. Training is reduced when there is only one system to learn to repair.

New Technology. With F3 standardization, new technology can be used as it appears. This increases mean time between failure (MTBF). This has the same impact whether caused by dual sourcing or standardization.

Supportability. With fewer parts to manage, supportability is increased.

Configuration Control. Configuration control efforts must be increased with F3. (This has the same impact whether caused by dual sourcing or standardization).

(Rosensteel, 1987:3-4)

F3 has one further potential disadvantage. Since the configuration of the item differs from contractor to contractor, the Government must return to the original manufacturer of each item for repair and spare parts. The Government may find itself once again seeking repair or repair parts from a sole source, a monopoly (Sellers, 1983:13; Robinson and Sullivan, 1986:17). With planning, it may be possible to avoid this trap. In the fighter engine request for proposal issued 18 May, 1983, the Air Force requested that dual sources be established for spare parts (Drewes, 1983:116). It worked.

> General Electric pledged not only to find and train dual sources, but also to stay with them until the Air Force was satisfied that second sources had really been established (Drewes, 1983:128,129).

Thus, despite having two form, fit, and function engines in inventory, the Air Force has the option of obtaining spare parts competitively.

Competition for spares and repair

With more than one manufacturer available, and using dual-sourcing methods where configurations are (theoretically) identical from manufacturer to manufacturer, there exists more than one source available capable of producing or repairing the system or any part of the system. In other words, if the items are indeed identical, the Government can competitively purchase spare parts and repair capability. If this is the case, the Government must make some further decisions. First, should the contracts be awarded sole source or competitively? Second, if the award is to be competitive, should it also be split among the bidders or should it be the traditional 'winner-take-all' ? Finally, if the award is to be split, how should this be done? In this case, the experience gained in awarding production contracts applies directly to the operation and support phase of the life cycle. Beltramo whole-heartedly recommends periodic winner-take-all competition. If that is impossible, then split awards should be made with caution (Beltramo, 1986:10).

Empirical evidence. The General Accounting Office (1984:20,34) reviewed early studies claiming substantial acquistion cost savings from the increased competition of dual sourcing. These studies reported cost savings of up to 30% after dual sourcing had been introduced. However, as the title of the General Accounting Office report (1984:title page) concludes, Cost Effectiveness of Dual Sourcing for Production Price Competition is Uncertain. The dramatic savings from dual sourcing cited

in the GAO report may not be as easy to obtain with larger systems. According to Grosson and Augusta, Sherbrooke and Associates reviewed seven earlier studies claiming dramatic savings. These dealt with large numbers of relatively inexpensive items. After studying larger purchases, they concluded that savings from competition on larger sytems are unpredictable (Grosson and Augusta, 1986:34). Grosson and Augusta's (1986:34) own study reached the same conclusion.

Beltramo's research substantiates these conclusions. Beltramo studied 25 major dual sourced weapons systems which had previously been purchased from a single source. Of the 25 systems examined, only six showed a decrease in price compared to the sole source price. In fact, 12 of the 25 showed an increase in price (Beltramo, 1986:6).

In summary, the Government has quite routinely obtained lower prices with smaller items like spare parts. But dual Sourcing of major systems is more risky.

Theory. Theory points to fundamental problems with the competitive affect of dual sourcing. Both theory and evidence indicate that the competitive affect is not as great as under the usual winner-take-all competition. Because the low bidder is guaranteed some portion of the award, there is less risk than being the low bidder and getting nothing. This guarantee allows the contractors to do some price gaming. For example, neither contractor should have as much incentive to hold down the cost of its bid on smaller quantities if its guaranteed at least that portion of the award.

This guaranteed split of the award changes the nature of the competition by altering the market. By guaranteeing a portion of the

award to all bidders, the Government is using the term 'competition' much more loosely than under the usual 'winner-take-all' procedure.

At the minimum under 'winner-take-all' competition, a monopsony exists, a market in which there are several sellers and one buyer. In a monopsony, sellers are deemed to have little control over price; therefore, effective competition exists (Department of Defense, 1980:2-3). By guaranteeing a portion of the award to each offeror, the Government is creating something akin to a bilateral monopoly with each contractor. It would be expected that a market that becomes more like a monopoly would be less competitive and prices would rise. This appears to be the case. However, the market still has some of the characteristics of an oligopoly. An oligopoly is a market with 'a small number of firms and a great deal of interdependence...among them' (Mansfield, 1985:364).

Interdependence refers to the way the oligopolist is influenced by the other firms' policies in the market. Since there are a small number of firms, each has a significant influence on price and quantity.

This difference in the market may cause the contractor to bid based on factors the Government has not even considered. The Government assumes that contractors want the larger portion of the award and are motivated by profit. Either or both of these conclusions may be false. Instead, such factors as production capacity, production costs compared to competitors, and reputation may be stronger influences (Meeker, 1984:8).

For example, if a company has all the production lined up that it wants, it may not be as motivated to go after the larger portion of the

award. It can raise its price on both the small and the large portion of the award. It can raise the price on the small portion of the award because it is guaranteed at least that. It can raise its price on the large portion to the point where it feels it would be worth its while to produce despite the lack of economical capacity.

Perhaps one competitor has lower production costs because of experience. This knowledge could influence bidding of both sides by influencing expectations. One contractor might not try for the larger amount and thus raise the price on the smaller quantity. Boger and Liao (1987:32) claim to have found evidence of this kind of bidding behavior.

Quantity Split Methods. In an attempt to increase competitive pressure to pre-dual-sourced levels, four other methods besides the usual fixed-percentage split have been used or proposed to split the award.

Solinsky developed a method which varied the split proportions according to the difference between the offeror's bids. This method fails to eliminate price gaming if both contactors are guilty of it (Boger and Liao, 1987:35; Kish, 1986:4). Meeker (1984:5) points out that a contractor can bid so that it receives the same profit no matter what proportion of the award it eventually receives.

Pelzer suggested including quality and other factors in the award formula. Boger and Liao see merit in this approach:

> [The model]...does not have specific measures to cope with ... price gaming strategies, [but] it recognizes the problem of unreasonable bid prices and makes a modest attempt to address the issue (Boger and Liao, 1987:35).

The Profit Related to Offers (PRO) Concept awards equal proportions to each offeror but gives a larger profit to the low offeror. This method also does not deal with a contractor satisfied with a minimum profit.

The Dual Competitive Award Method (DCAM) requires each contractor to submit a learning curve estimate with each quantity requested. This data is massaged to calculate the split ratio that yields the lowest cost to the Government. Boger and Liao (1987:35) conclude that this method also does not prevent price gaming. It does, however, like the Pelzer method, make a modest attempt to relate the award quantity to pricing behavior.

Boger and Liao (1987:35) thus find that none of the present strategies prevent price gaming. Meeker believes the problem cannot be solved. He concludes that 'it is impossible to engender competition with profit as the motive by splitting the buy' (Meeker, 1984:8). He also concludes that'...any scheme that does not provide for zero allocation (removal of the guaranteed award) will engender reverse competition' (Meeker, 1984:5).

Why then is there a price decrease in some cases? Sellers (1984:8) cites other factors which may be more important than profit. He mentions 'prestige, gross sales, use of idle capacity, and future business'. He also believes the ever-watchful contracting officer can catch price gaming and negotiate effectively with the contractors.

Conclusion

Although little has been written on the effect of dual sourcing on operation and support costs, experts feel that the configuration control

issue (destandardization) and the opportunity to competitively award repair and spare parts contracts differ from the operation and support environment of sole-source production. Experts feel configuration control plays a major role when dual sourcing is introduced. They believe there will be problems when more than one contractor is manufacturing the same item. But to the extent that the items are identical from manufacturer to manufacturer (F3 is not used), the Government has the option of competitively awarding mainentance, repair, and spare parts contracts. Despite the theoretical problems with the competitive effect of dual sourcing, spare parts prices will probably be lower. This may not be true of major systems.

If F3 is used to create the second source, the configuration control problems are by-passed. But a host of other problems appear. These problems stem from destandardization. The benefits of standardization are often the problems of F3 dual sourcing. However, with planning, some of these problems can be overcome.

III. Methodology

Chapter Overview

This chapter describes how the impact of dual sourcing on operation and support was examined. The first task was selection of a life-cycle cost model. The second task was validation of the model. This was attempted using items in inventory, case studies, and expert opinion. The third task was collecting and describing other impact (other than cost) revealed during data collection.

The ultimate goal would be an operation and support cost model sensitive to dual sourcing and a complete description of other, non-cost impacts. However, since this research has not been attempted before, this study is more of an exploration of the field.

Selection of the Life-cycle Cost Model

Model Evaluation Criteria. In order to evaluate costs, some type of life-cycle cost model must be used. Mills (1977:16-19) suggests choosing a model using the criteria shown in Table II.

TABLE II

Criteria for Evaluating Life-cycle Cost Models

Completeness
Sensitivity
Validity
Availability of Input Data
Documentation

Completeness. A model should include all relevant cost elements. In this case it must include all elements likely to be

affected by dual sourcing, particularly those mentioned in the literature reviewed in Chapter II.

Sensitivity. This criterion recognizes that a complete model may include cost elements not relevant to the decision at hand. An analyst can pare a model to only the cost elements which concern the immediate problem. With extraneous cost categories removed, the model is easier to use, and remains 'sensitive' to the problem. For the purposes of this study, if a standard life-cycle cost model is used, some cost elements may be eliminated if not relevant to dual sourcing decisions. On the other hand, some cost elements may need to be added so that the model is sensitive to all the affects of dual sourcing.

Validity. 'The validity of a life cycle cost model is a measure of how well the model represents the real-world environment in question' (Mills, 1977:17). This is essentially the result of fulfilling the previous two criteria. A 'complete' model is representative; it is sensitive when it concerns the 'environment in question'.

Availability of Input Data. If the type of data required by a model is either not available or is of dubious quality, then the model and the results from the model will not be useful.

Documentation. If the assumptions and methods used in the model are unknown to the user, the user cannot determine the validity of the analysis.

Level of Detail. One other criterion should be added: level of detail. May (1982:4-1) says that most models stem from either the 'annual squadron O&S cost or the Logistic Support Cost (LSC) model'.

Because of the level of detail required, this study needs a model along the lines of the LSC model. As he says,

> The LSC style models are very appropriate in evaluating detailed design alternatives at the component level. For example, they could be useful in the selection of one contractor's equipment, such as an inertial navigation set, versus that of another contractor (May, 1982:4-6).

Selection of Dual-sourced Items

To exercise the chosen model, appropriate items must be found. The goal was to find assemblies and subassemblies which had been dual sourced during production. The operational definition used was 'items in inventory which have been produced by two or more manufacturers'.

Accordingly, the Directorate for Material Policy, HQ-AFLC/MML, searched the D043 database for the items. The D043 database catalogs all items in the Air Force inventory. It has the search capability to select the items of interest to the study. D043 selected items meeting the criteria shown in Table III (Appendix B contains further detail--such as exact codes used):

TABLE III

Search Criteria

1. Purchased under competitive conditions
2. Item is repairable equipment
3. Interchangeable or substitutable with other items
4. Managed by Warner-Robins Air Logistics Center

Competitive Conditions. This was defined as an Acquisition Method Code (AMC) of 2 or 3; i.e., the item had been purchased under competitive conditions at least once.

Repairable Equipment Limitation. This limitation was designed to limit selection to items which are repairable. The literature review

singled out costs stemming from repair as an category likely to be affected by dual sourcing. In other words, a throw-away item would not pick up many of the costs that need to be examined.

Interchangability and Substitution. Interchangability and Substitutability (I & S) codes were used to find items which were produced by more than one manufacturer in inventory. For example, when an item manager receives a F3 item, a unique national stock number (NSN) is assigned to the configuration from each manufacturer. Since the internal configuration of the item from each manufacturer is different, repair may require different handling of the item depending on which manufacturer produced it. To identify the different NSNs as the same functional item, item managers use I & S phrase codes which identify the F3 relationship among them.

Limitation to Warner-Robins Managed Items. Because of time and cost considerations, items were selected from the closest Air Logistics Center, Warner-Robins AFB.

Data Collection

To validate this study, three sources of data were examined: the Visibility and Management of Operating and Support Cost (VAMOSC) system, experts, and case studies.

VAMOSC. The D043 database identified the items to study; VAMOSC was to supply cost data on the selected items. VAMOSC is the Air Force O & S cost library. It gathers and pools data from databases throughout the Air Force (Department of the Air Force, 1985:10-11). VAMOSC was developed because of the concerns mentioned in Chapter I that O&S costs were getting out of hand.

> The DOD came to realize that all available resources could be depleted in the support of existing weapon systems, with no funds remaining to develop new ones (Department of the Air Force, 1985:4).

VAMOSC should be the ideal system from which to obtain data for this study. One of its purposes is to '...provide improved logistics support cost information for use in acquisition planning...' (Department of the Air Force, 1985:5). Dual sourcing is certainly a decision which requires careful planning.

VAMOSC is actually three O&S cost libraries:

1. The Weapon Systems Support Cost System (WSSC)
2. The Communications-Electronics System (C-E)
3. The Component Support Cost System (CSCS).

Since this study examines subassemblies, it uses the CSCS. Also, at this time the C-E system is not yet developed, and the WSSC system does not provide the level of detail necessary.

Experts. When available, experts were also consulted. Although empirical data certainly has its disciples, expert opinion should not be slighted. May (1982:5-14) feels that 'functional area experts' are the '...most important data source (for) the O&S cost analyst...'.

Case Studies. When possible, relevant cases were used to evaluate dual sourcing's impact on operation and support.

IV. Findings and Analysis

Chapter Overview

After a review of component-level life-cycle cost models, the Cost Analysis Strategy Assessment (CASA) model was chosen as the most useful for this thesis. The D043 database crossreferencing capability uncovered items which had been produced by more than one manufacturer in inventory and of identical or F3 configuration. But VAMOSC proved unable, at this time, to supply the necessary cost data for those items. Consequently, an empirical exercise of the model must wait for the maturation and expansion of VAMOSC. However, a search revealed experts and case studies with data relevant to this study.

The Life-Cycle Cost Model

Selection of the Life-cycle Cost Model. Cost models reviewed were the CASA, Life Cycle Cost Analysis (LCCA), Program Life Cycle Cost Documentation (LCC-2), Standardization Evaluation Program (STEP), and Logistic Support Cost (LSC) models (Hunt, 1983; Defense Systems Management College, 1986; May, 1982). Of the LSC type, component-level, models reviewed, the CASA model most closely fulfills the requirements of this study--particularly completeness. It contains, in many cases, the cost elements by name which should be affected by dual sourcing.

Tables IV and V list the CASA cost elements with the expected dual-sourcing impact. Table IV lists those effects expected from dual-sourced items which are identical in configuration. Table V lists impacts expected from dual-sourced, form, fit, and function items. The left column of each table lists CASA operation and support cost

elements (Defense Systems Management College, 1986:3-28,29). The right column of each table lists the impact, if any, that dual sourcing is believed to have on the corresponding cost element shown in the left column. All impacts use the sole-source, single producer method of acquisition as the basis for comparison. In other words, they show what change there would be from the sole-source environment to the corresponding dual-sourced environment.

Table IV

Impact of Identically Configured Dual Sourced Items on CASA Cost Elements

CASA Cost Elements	Dual-sourcing Effects
1. Operation labor.	No impact.
2. Repair.	No impact.
3. Support equipment maintenance.	No impact.
4. Recurring training.	No impact.
5. Repair parts and materials.	Lower cost through competition.
6. Repair consumables.	No impact.
7. Condemnation spares replenishment.	Lower cost through Competition.
8. Technical data revisions.	Configuration control cost increase.
9. Transportation.	No impact.
10. Recurring facilities.	No impact.
11. Contractor services.	Competition possible.
12. Engineering changes.	Configuration control must be increased.
13. Miscellaneous.	No impact.

TABLE V

Impact of Form, Fit, and Function Dual-Sourcing
on CASA Cost Elements

CASA Cost Elements	Dual-sourcing Effects
1. Operation labor.	No impact.
2. Repair.	No impact.
3. Support equipment maintenance.	More equipment.
4. Recurring training.	Additional training.
5. Repair parts and materials.	More parts unless special measures are taken.
6. Repair consumables.	No impact.
7. Condemnation spares replenishment.	Competition possible. Expected price reduction.
8. Technical data revisions.	No impact.
9. Transportation.	No impact.
10. Recurring facilities.	More facilities required.
11. Contractor services.	No impact.
12. Engineering changes.	No impact.
13. Miscellaneous.	No impact.

Since four of the cost elements are not expected to be affected by dual sourcing (1, 2, 6, 13), they were dropped from the model for the purposes of this thesis. The result was a standard operation and support cost model which can be used to assess dual sourcing operation and support impacts. The nine CASA cost elements are at Appendix C.

Selection of Dual-sourced Items. The D043 database yielded about 30 possible items. This was out of approximately 2.1 Million items. The resulting list consisted mostly of avionics. For example, among the items were an azimuth indicator, a radar receiver, a terrain computer, a gyro, and a host of circuit cards. But other types of items were also included. Examples are an aircraft fuel tank, a duplicating machine, and a band saw.

This seems to indicate that very few items are impacted by dual sourcing. This may be true. However, there may be many items which are

nevertheless impacted. Any part which is part of a dual-sourced subassembly may be affected. This was not pursued because the cost data was not available through VAMOSC as shown below.

Cost Data. Once appropriate items were identified, management of the Visibility and Management of Operating and Support Cost (VAMOSC) system was requested to supply the required data on those items. However, this proved impossible. One reason is the newness of the system. The VAMOSC system is currently still in development. In the past, data was not consistently collected and validated. Past data is therefore incomplete and unreliable. Only 1987 for CSCS data has been validated. No data for 1988 has yet been entered and validated. This leaves only one year's worth of useable data (Hunt, 1988). Unfortunately, the only way an empirical comparison of sole sourcing to dual sourcing can be made is by comparing sole-sourced and dual-sourced portions of the life of an item which has had both types of procurement in its history. Beltramo (1986) used this method to evaluate acquisition costs. VAMOSC may be a valuable source in the future, but this study was attempted too early in its life.

Another caution is in order.

> ...some costs cannot be directly identified to a system or component, necessitating the use of factors or algorithms to allocate these costs (Department of the Air Force, 1985:4).

Allocation techniques may--or may not--be correct for dual sourcing studies. If they are not correct for dual sourcing, significant effort may be necessary to correct them.

Besides currently missing or unvalidated data and suspect allocation techniques, another problem was identified. VAMOSC does not

track several of the needed cost categories, or cost elements. Since VAMOSC is theoretically storing all relevant and available O & S cost data, the missing data may not even be available anywhere in the Air Force. The necessary cost elements which were identified as missing are listed in Table VI. This was determined by comparing the list of cost elements in the model with those reported to be available (Department of the Air Force, 1985:7,8;Hunt, 1988). The cost elements are numbered as they appear in all previous tables.

TABLE VI

Necessary Cost Elements Not Captured by VAMOSC

3. Support equipment maintenance.
4. Recurring training.
8. Technical data revisions.
9. Recurring facilities.
11. Contractor services.
12. Engineering changes.

It is important to point out that the VAMOSC office is not responsible for unreported cost elements. They are only authorized to function as a cost library.

> The VAMOSC system operates under a constraint that no new data systems be developed. All data sources must be existing DOD data sources...
>
> VAMOSC is not a cost accounting system, cost estimating system, or budget system. It is a cost collecting system (Department of the Air Force, 1985:4).

Conclusion of the Data Search. The search for dual-sourced subsystems was successful, and an appropriate model was developed. But the impact of dual-sourcing on the items could not be evaluated without the cost data from VAMOSC. In other words, the cost model could not be exercised.

Case Studies and Expert Opinion

Since the empirical data necessary to exercise the model are not yet available, and since they could not be estimated with confidence, case studies and expert opinion remain the only way to evaluate the operation and support impacts of dual sourcing. Sufficient time was not available to track down the program managers, item managers, and engineers who deal with the items identified by the D043 search.

Case Studies. These case were found while interviewing program managers at Headquarters, Air Force Logistics Center, and analysts at the Air Force Acquisition Logistics Center at Wright-Patterson AFB. They concern form, fit, and function dual sourcing.

The Great Engine War--the Post War Story. In 1983 the Air Force released a request for proposal for an estimated 2,000 engines for the F-15s and F-16s spanning fiscal years 1985-1990. On 3 February 1984, a split award was announced. General Electric was awarded 75% of the 1985 requirement. Pratt and Whitney received the remainder. This dual sourcing competition is still continuing.

An interview with Major Hicks (1988) at Headquarters Air Force Logistics Center (HQ AFLC) revealed some interesting logistical impacts from this dual sourcing decision. The F-16 airframe uses both types of engines. Since the engines have different proportions, the airframe manufacturer produces the F-16 with two types of engine bays. In other words, not only are the engines dissimilar internally, they are not interchangable (no fit!) between the two aircraft configurations. To avoid additional logistics costs, such as duplicate special tooling throughout the world, the Air Force stations the F-16s with one kind of

engine in the Pacific (General Electric) and the other in Europe (Pratt and Whitney). This reduces supportability. For example, if a Pacific-based F-16 squadron were to deploy to Europe, it could not land at a European F-16 base and expect complete engine service. Repair capability would be limited unless a 'Pacific' machine shop were sent with it.

The alternative would be duplicate tooling, spares inventory, training, and facilities throughout the world. Apparently, the Air Force has decided that reduced supportability is more palatable than increased cost.

The A-10 and Standardization. Since F3 dual-sourcing destandardizes (as compared to other dual sourcing approaches), standardization studies are relevant to this thesis. In other words, what standardization does, F3 dual sourcing is likely to undo. According to Ernest Curry, life-cycle cost analyst,

> The A-10 aircraft, used as the baseline, showed about a four fold increase in readiness when additional aircraft (i.e., F-15, F-16) use the same mission critical avionics. This increased readiness resulted from the larger combined pool of depot spares for each aircraft to draw on. The study also showed a cost savings for the A-10 when other aircraft shared in the cost of depot spares (Curry, undateda:2).

This suggests that supportability may be decreased by form, fit, and function dual sourcing, and that readiness may be decreased as well.

Experts. Since there were no dual-sourcing operation and support experts available, this thesis relied on experts in the area of standardization. The experts in standardization also, like the cases previously mentioned, aid in the understanding of F3 dual sourcing.

Piece Part Standardization. Milligan and Tonar of the Defense Electronic Supply Center (1988) believe that 60% to 80% of all parts in avionics are standard piece parts. Thus, the addition of another dissimilar piece of avionics equipment in the inventory does not require the stocking of a totally new set of parts for repair. It is probable that form, fit, and function dual-sourced subsystems would have a large percentage of common piece parts because they perform similar functions. Therefore, despite having different internal configurations, two F3 systems would not introduce double the number of spare parts that one sole-source system would likely introduce.

Still, additional parts would be introduced. The Directorate of Engineering Standardization at the Defense Electronics Supply Center (1988:C-2 to C-5) has estimates of the yearly recurring cost of each additional piece part entered into inventory. Estimates range from $225 per year to about $420 per year. The Directorate believes that each additional piece part costs the Government at least $2,637 over its average 10 year life. In short, while the additional cost of spare parts for F3 subsystems may not be as dramatic as it would seem at first glance, the costs may be significant.

Avionics Standardization (ASD). Perhaps more interesting are the standardization studies done on subsystems. Curry cites a Logistics Management Institute study which claims that the 'minimum savings occuring from standardization are on the order of 13% to 25%'. However, he says that, 'Most of the savings are in one time costs which can be avoided each time a standard item is used in lieu of a unique development' (Curry, undateda:2). Since most of the savings are in one

time costs, it follows that no more than 6.5% to 12.5% can come from operations and support. Assuming that F3 dual sourcing is a close reciprocal of standardization, the extra O & S costs associated with F3 dual sourcing can be no more than 6.5% to 12.5% of the sole-source costs.

Curry says that standardization has the following things related to O & S to recommend it.

TABLE VII

Attributes of Standardization

Reliability improvement
Skills availability
Improved logistics support
Technology transparency
Interoperability/Interchangability
Increased availability

(Curry, 1988)

Support and Test Equipment with F3 items. Edward Curry mentioned that the cost of special support and test equipment is higher with F3 items than identical items. He said that even though internal configurations differ, that test equipment can sometimes be bought which can handle all the configurations. It will probably be more expensive than a piece of equipment handling only one configuration, but the cost will not be twice that of one configuration (Curry,1988).

With the close correlation between the list of cost elements impacted by F3 dual sourcing and the list in Table VII, the assumption that the impact of standardization on operation and support is often the opposite of that of F3 is probably a good one. In other words, the things that make standardization worth pursuing also make F3 dual sourcing less attractive. This is because F3 dual sourcing

destandardizes. Instead of one item performing a function, the Air Force must manage two or more which differ internally.

Summary

An examination of the impact of dual sourcing on operation and support was attempted using a cost model, case studies, and experts.

A derivitative of the CASA model was developed for use with items identified by the D043 inventory database. However, the CSCS system of VAMOSC was unable to provide cost data for those items. Operational experience with the dual-sourced fighter engines showed that the operation costs of F3 items can lead to a choice of either high cost or reduced supportability. Standardization studies with the A-10 suggest that readiness may also be reduced with F3 when compared to sole-sourced buys of identical items. Finally, experts in standardization feel that in some ways the impact of F3 may not be as dramatic as it would at first appear.

V. Summary, Conclusions, and Recommendations

Summary and Conclusions

The literature and original research done for this thesis reveal that impact of dual sourcing on operation and support depends primarily upon the degree to which the resulting items from the various manufacturers are dissimilar. This is determined by the method used to create additional sources. Four of the methods that create additional production sources result in theoretically identical items. One (form, fit, and function) results in items which are similar externally, but which differ internally.

Identical Items. Identical items result from four of the methods used to create or maintain other sources: technical data package, directed licensing, leader-follower, and contractor teaming. The literature review revealed that during the operation and support phase of the life cycle, the benefit comes from the ability to competitively acquire spare parts, replacement spares, and maintenance. Studies show that significant savings can result for small contracts when competition is introduced. This suggests that the competition for spares, replacement parts, and maintenance will probably be beneficial to the Government. This may come at the cost of extra configuration control efforts--and perhaps the minor configuration differences which result despite everyone's best efforts. Data to test the literature concerning identically configured dual-sourced items were not available during this thesis. However, the literature reported actual dual sourcing cases in the Navy. Thus, many of the conclusions from the literature have an empirical basis.

Form, Fit, and Function Items. Those items which are second sourced using form, fit, and function specifications present a considerably different case. Of course, replacement spares can be bought competitively, but spare parts, maintenance, special tooling and support equipment, training, and facilities costs may be adversly impacted.

With internal configurations which differ from manufacturer to manufacturer, the Air Force must decide whether or not to repair items itself. It it does, the spare parts inventory, maintenance of special tooling and support equipment required for each configuration, training for each configuration, and facilities to store the extra equipment may be higher. This can be significant. Because of these concerns, the Air Force stationed form, fit, and function F-16s on different sides of the world. As a result, supportability has suffered. On the other hand, standardization efforts on piece parts may considerably reduce the otherwise heavy burden that would be expected from stocking spare parts for interally different items. Research suggests that piece part standardization yields subsystems with from 60% to 80% standard piece parts. Still, entry of two F3 items may cause an increase in piece part inventory which is from 20% to 40% higher than that caused by the entry into the inventory of one new system or subsystem.

With planning, the Air Force has been able to avoid another cost suggested by the literature. The literature suggests that spare part costs will be higher with F3 because they must be bought from the original manufacturer of each configuratrion. The dual sourcing of fighter engines shows that this can be avoided if the Air Force

specifies in the contract that addition sources for spare parts must be developed. Also, with care, support and test equipment can be bought that--although more expensive than otherwise--are less expensive than unique sets of equipment for each configuration. This would, in turn, probably reduce the facilities required to store this equipment--and the cost of maintaining it when compared to multiple sets. Thus, although the cost associated with many cost elements may be higher than with identical configurations, this higher cost may be avoided with planning or may not be large as one might otherwise think.

Conclusion

As an exploratory study, this research has fulfilled its purpose of attempting 'to define the problem more specifically' (Emory, 1985:58). It has defined which elements are impacted by dual sourcing. It has also suggested which ones may be more--or--less significant. Finally, it has revealed that dual sourcing can be managed to improve its benefit to the Air Force. Finally, a cost model has been suggested with which the cost effect might be measured. However, with the problem mapped out, much still remains to be done. Many of the cost elements lack any empirical basis upon which to test the effects of dual sourcing.

Recommendations

Acquisition price savings on dual-sourced programs range from as high as 25% to as low as a negative 36% (Beltramo, 1986:5). With the benefits of dual sourcing as unpredictable during acquisition as history has shown them to be, the Government must remember that operation not only is the only useful portion of the system's life cycle, it is also

typically the most expensive. Dual sourcing without knowing the impact on the largest portion of costs and the impact on supportability and readiness may reveal dual sourcing to be more risky than it is even now known to be. On the other hand, with proper management and awareness of the options, these risks can be reduced or eliminated--as has already been done with spare parts procurement.

In view of the above, the Air Force should attempt to quantify the cost effect of dual sourcing when the VAMOSC system has sufficiently matured. It may be worthwhile to consider allowing VAMOSC to collect the cost elements currently lacking which would enable an empirical study over a broad range of programs. Otherwise, a program by program study may have to be done with a large cost in time and effort.

Appendix A: Definitions

Appendix Overview

This appendix contains the specialized terms used in the thesis.

Avionics equipment. "All the electronic and electromechanical systems and subsystems (hardware and software) installed in aircraft or attached to it " (Department of the Air Force, 1978:1-1). For example, avionics are found in these functional areas:

> communications, navigation, weapons delivery, identification, instrumentation, electronic warfare, reconnaissance, flight controls, engine controls, power distribution, and support equipment (Ackerson, 1980:1-1).

Contractor Teaming. A method of creating another source for competition. During contractor teaming, contractors jointly develop the product or system. Before production begins, the team dissolves. Then the former team members compete against each other for the right to produce the item.

Design to Cost (DTC). Design to cost establishes cost as a design goal.

> "Design-to-cost" is a concept that establishes cost elements as management goals to achieve the best balance between life-cycle cost, acceptable performance, and schedule. Under this concept, cost is a design constraint during the design and development phases and a management discipline throughout the acquisition and operation of the system or equipment (Department of Defense, General Services Administration, and National Aeronautical and Space Administration, 1984:7.101).

In other words, cost is equally as important as other goals like technical performance and schedule.

Directed Licensing. A method of producing other sources for competition. Under directed licensing, the original source provides

other sources with data and assistance so that they can produce the item as well. This service is provided in exchange for a royalty fee.

Dual Sourcing. This study uses the General Accounting office (GAO) (1984:i) definition of dual sourcing:

> ...a competitive technique wherein each of two or more sources concurrently produces the same product for the same buying office, with award of the larger share of quantities usually going to the lowest price source.

Form, Fit, and Function (FFF or F3). A method used to allow more than one contractor to produce an item. With this method, the contractor provides an item which performs just like that of the original source. Usually it must be able to fit in the same location and weigh the same as the original. However, the specifics of the internal configuration are left up to the contractor.

Leader-Follower. A method of developing other sources for competition. Leader-follower is similar to directed licensing, but there is no royalty fee.

Life-cycle Cost (LCC). The Federal Acquisition Regulation (FAR) defines LCC like other Government regulations:

> 'Life-cycle-cost' means the total cost to the Government of acquiring, operating, supporting, and (if applicable) disposing of the items being acquired (Department of Defense, General Services Administration, and National Aeronautical and Space Administration, 1984:7.101).

In short, life-cycle cost is the 'total cost to the Government for a system over its full life' (Department of the Air Force, 1986:11).

Life-cycle Costing. Seldon's definition of life-cycle costing is 'The consideration of life cycle cost in choices or decisions among different courses of action' (Seldon, 1979:269).

> The objective of life cycle costing is to lower a system's life cycle cost by striking a balance between acquisition and O & S costs' (Sims, 1978:12).

Modular Standardization. See standardization. This is standardization at the circuit card level. The circuit cards, or modules, need not be identical; F3 is also considered standardization.

Piece Part Standardization. See standardization. For electronic components, the Directorate of Engineering Standardization, Parts Control Division at the Defense Electronics Supply Center, DESC-EP, approves electronic components for use on avionics. If a contractor wants to use a part not on the approved list, approval must be obtained from this office.

Standardization.

> [The adoption] on the broadest possible basis ... of common, compatible, or interchangeable supplies, components, weapons, or equipment (Ackerson and Baum, 1980:1-5).

Standard Avionics. 'Those pieces of common avionics equipment that perform a particular function for more than one system' (Department of the Air Force, 1978, 1978:1-1).

Subsystem Standardization. See standardization. This includes interchangeable radios, navigation systems, etc. The subsystems need not be identical; F3 is also used.

Technical Data Package. A method of creating other sources for competition. In contrast to the form, fit, and function method, the technical data package method requires sources to produce an item identical to that of the original source--internally as well as externally. For this purpose the Government provides contractors with a data package completely describing the item.

Winner-take-all. The GAO defines dual sourcing as usually meaning splitting an awarded quantity among the bidding contractors. In contrast, the more traditional method is to award the total quantity to the bidder with the best offer. This is called the 'winner-take-all' method. Beltramo points out that not splitting the award does not necessarily rule out dual sourcing. In fact, he recommends annual winner-take-all awards if possible (Beltramo, 1986:2). This method could technically fit the GAO definition. If production lasted longer than a year, each source would be concurrently producing--a requirement of the GAO definition.

Appendix B: Codes Used to Select Items from the D043 Database

HQ-AFLC/MML suggested the following codes be used to find items in inventory which have been produced by more than one manufacturer and which are either identical from each manufacturer or form, fit, and function.

Category	Code Used	Significance
LOA	22	Repairable item
SOS	FLZ	Managed by Warner Robins AFB
AMC	2 or 3	Competitive Purchase
PHR	E, F, G, H, 7	Interchangable or Substitutable Items. Links those items which are F3.

Appendix C: Proposed Model

This appendix presents the suggested model. It contains those cost elements which are expected to be influenced by dual sourcing. The cost elements are:

Support equipment maintenance.
Recurring training.
Repair parts and materials.
Condemnation spares replenishment.
Technical data revisions.
Recurring facilities.
Contractor services.

Total operation and support cost is the sum of the costs contained in the individual cost elements listed above. These cost elements are defined as they are in the CASA manual (Department of Defense, 1986a:3-30 to 3-38).

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[redacted]

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GCM/LSQ/88S-9	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION School of Systems and Logistics 6b. OFFICE SYMBOL (If applicable) AFIT/LSQ	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Air Force Institute of Technology Wright-Patterson AFB OH 45433-6583	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) See Box 19	
12. PERSONAL AUTHOR(S) Stephen C. Miller, B.S., CAPT, USAF	
13a. TYPE OF REPORT MS Thesis	13b. TIME COVERED FROM _____ TO _____
14. DATE OF REPORT (Year, Month, Day) 1988 September	15. PAGE COUNT 61
16. SUPPLEMENTARY NOTATION	

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Life Cycle Costs, Dual Sourcing, Operation and Support
05	03		
15	05		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Title: A STUDY OF THE EFFECT OF DUAL SOURCING ON OPERATION AND SUPPORT

Thesis Chairman: Roland D. Kankey, Ph.D.
Assistant Professor of Quantitative Management

Approved for public release IAW AFR 190-1.

WILLIAM A. MAJER 17 Oct 88
Associate Dean
School of Systems and Logistics
Air Force Institute of Technology (AU)
Wright-Patterson AFB OH 45433

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL Roland D. Kankey, Ph.D.	22b. TELEPHONE (Include Area Code) (513) 255-8410	22c. OFFICE SYMBOL AFIT/LSQ

DD Form 1473, JUN 86 *Previous editions are obsolete.* SECURITY CLASSIFICATION OF THIS PAGE

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Past research on dual sourcing dealt with acquisition. Since typically the majority of a major system's cost occurs during operation and support, this has left a large gap in the literature. Also, the impact of dual sourcing on supportability and readiness has not been examined. This thesis is a first attempt to plug that gap.

This was attempted using a life-cycle cost model, through case studies, and expert opinion. Although an appropriate cost model was developed, cost data was not available to exercise it. Current databases have not been in place long enough to provide the necessary data. Also, many of the cost elements of interest are not collected.

The literature, case studies, and experts, revealed that the primary determinant of the impact of dual sourcing on operation and support comes from the degree of configuration standardization imposed by the method used to create or maintain additional sources. For this reason, experts in standardization provided a wealth of detail useful to this study.

Four of the methods used to create additional sources put identical items in inventory. Form, fit, and function dual sourcing does not. If identical items are produced, there may be configuration control problems among manufacturers, but competition in spare parts and maintenance can be a benefit.

The literature predicted that form, fit, and function dual sourcing would produce additional costs and inconveniences during operation and support. This resulted from maintaining multiple configurations of an item in inventory. The case studies and experts suggest that this can indeed be the case, but that adequate planning can reduce negative impacts significantly.